ENGINEERING PASSES AND AERIAL TARGETS

INTRODUCTION

In this section, detailed attention is given to the use of aerial targets. First, the use of aerial targets is justified. That is, we answer the dual question, "What can be done with target photography that cannot be done otherwise and why is this useful?" Second, we discuss the role of atmospheric scattering (haze), as this is central to the choice of a target form. While atmospheric turbulence ("seeing" or refractive index inhomogeneity) is not germane to the C/M system and is therefore not discussed, it must not be ignored for higher resolution systems (e.g., G). Third, specific types of targets are described and the implications of using these are explained. Fourth, target fabrication and location are discussed. Fifth, and last, recommendations are made.

THE NEED FOR AERIAL TARGETS

The quality of an aerial photograph is primarily determined by the nature of the atmosphere, the ability of the lens to resolve detail, the stillness and focus of the image impinging on the film, and the processing and granularity of the film. Each of these independent contributions to overall quality can be separately measured - and should be during camera development and test - but the only complete test of an aerial camera is an aerial photograph of an object sufficiently well known so that uncertainties about the object are negligible compared to other parameters of interest.

As can readily be imagined, the instrumentation required to accurately measure each independent variable simultaneously is overwhelming, so, as a

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practical matter, such a program is intelligently approximated, at best. For instance, temperature of the lens and barrel are measured, and perhaps film flatness is measured, but the location of the true aerial image relative to the film is very difficult to check other than by the photography itself. Similarly, the relevant properties of the atmosphere could be measured - if they ever become well known - but the effect of the atmosphere can be subtracted out of the quality equation if the object is well known, without any measurement of the atmosphere. Thus, the answer to the question, "What can be done with target photography that cannot be done otherwise?" is - nothing, in theory; but, in practice, target photography provides the simplest, cheapest, most accurate measure of camera performance without a weight or space penalty in the airborne package.

Is this useful? The answer here depends on the intentions of the measurer. If the target photography is merely recorded and no improvements are to be attempted, then there is no point in making any measurement or in conducting engineering passes, either of a component or the complete system. However, if improvements are to be attempted, and we presume this to be the case, then an accurate measurement is needed beforehand to assist in diagnosis, and is needed afterwards as a test of success.

Target photography can assure good ground truth and the ambiguities can easily be made negligible for any aerial camera of interest. Similarly, appropriate ground targets will be immune to the effect of atmospheric scattering on photographic quality.

However, target photography cannot pinpoint a faulty component, although it may well identify the nature of a deficiency, so target photography should

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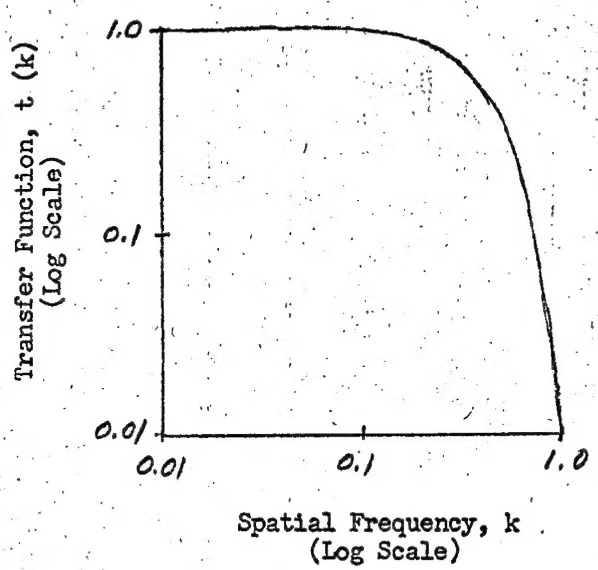
be conducted concurrently with carefully instrumented component measurement during engineering passes. The concurrency of photography and instrumentation provides a necessary consistency check on both outputs, and is the standard and most valuable test for conventional aerial cameras. Also, target photography reveals nothing about the usefulness of the photography to the photo-interpreter, and this must be investigated by other means.

THE ROLE OF ATMOSPHERIC SCATTERING (HAZE)

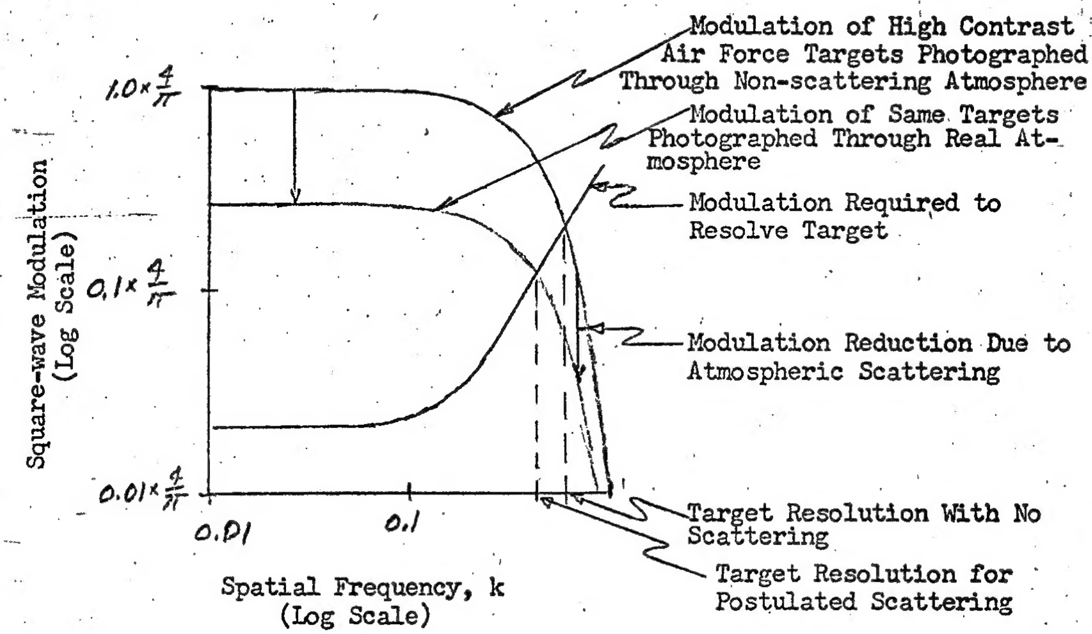
Atmospheric scattering (or haze) lowers the brightness modulation (or contrast) of an aerial photograph, primarily by adding non-image forming brightness, analogously to the addition of an extraneous D. C. voltage to a mixed A. C. and D. C. signal voltage. A reduction of signal (brightness) modulation means that the resolution of a three-bar or other target form will be lowered in a predictable way, as illustrated in Figure __(1)___. While the relationship of resolution and interpretability is not yet established, the usefulness of a reduced modulation photograph for interpretation will also be reduced. Hence, both target resolution and information will be lower in a hazy atmosphere than in a clear atmosphere. The important aspect is that camera deficiencies can produce similar losses, as illustrated in Figure__(2)_, and it is thus important to distinguish those losses due to atmospheric scattering from those due to camera deficiencies. In fact, because of atmospheric scattering, it is possible to obtain poorer photographs with a superior camera, as illustrated in Figure _(3)__. There is no value in modifying an operational camera system if its quality variations (in terms of interpretability, for instance) are caused solely by atmospheric scattering variations, so it is very important to assess atmospheric scattering, or to choose a target form which is immune to modulation reduction.

The effect of atmospheric scattering is indistinguishable from a veiling glare or light leak just as the analogous voltage applied to a voltmeter

Figure __(1)__

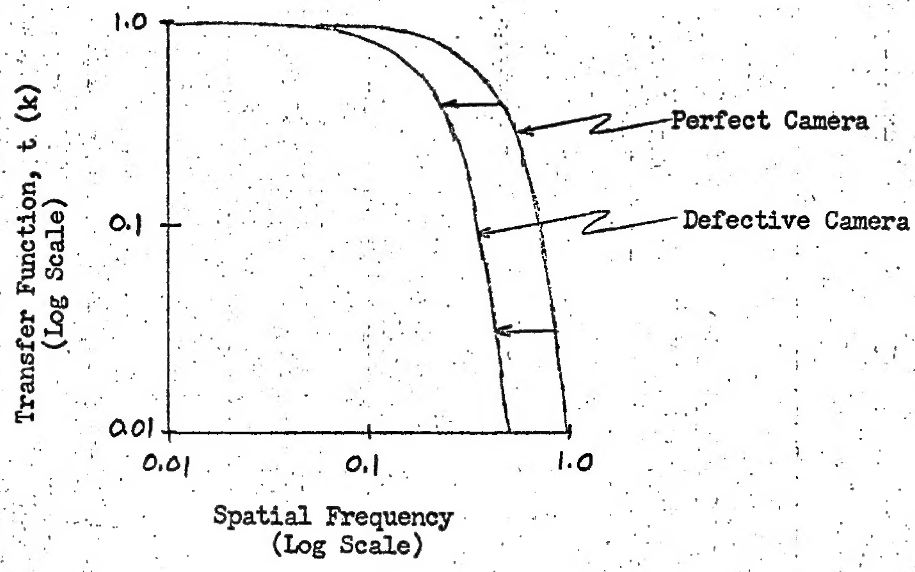


A - Transfer Function of Aerial Camera

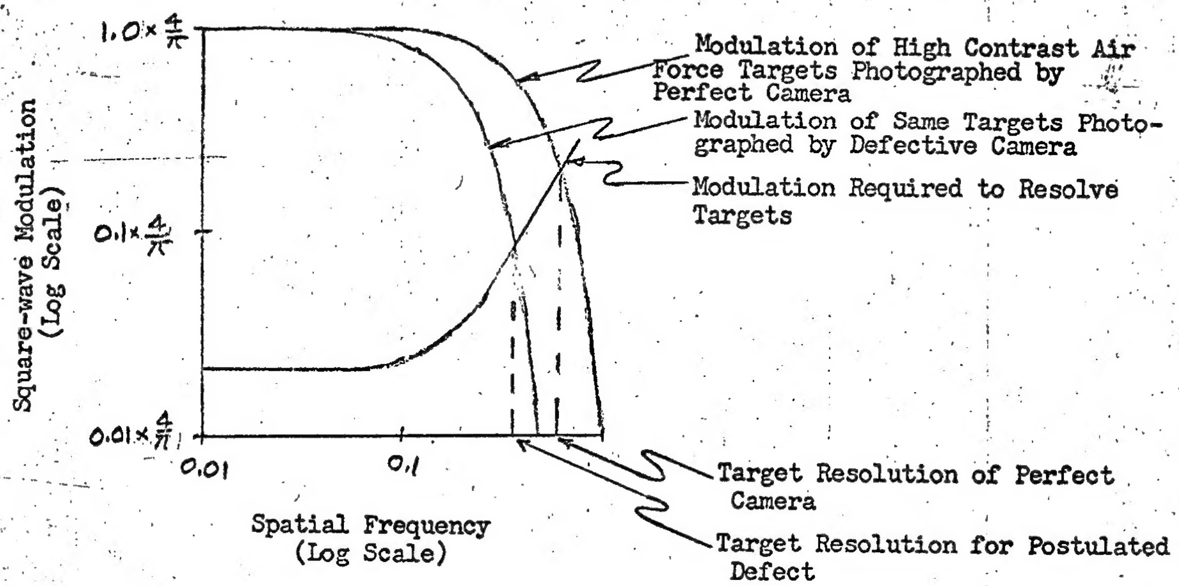


B - Modulation Reduction and Resolution

Figure __(2)__

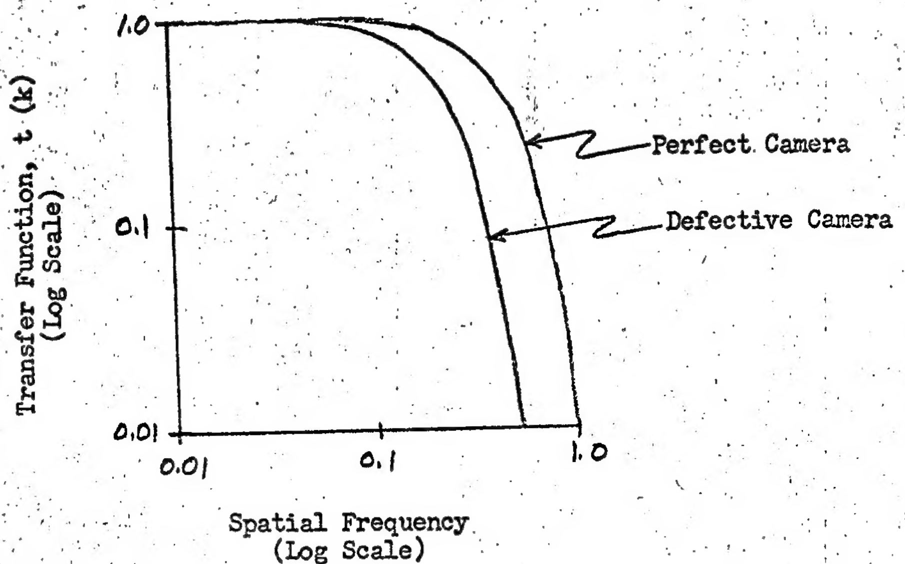


A - Transfer Functions of Aerial Camera

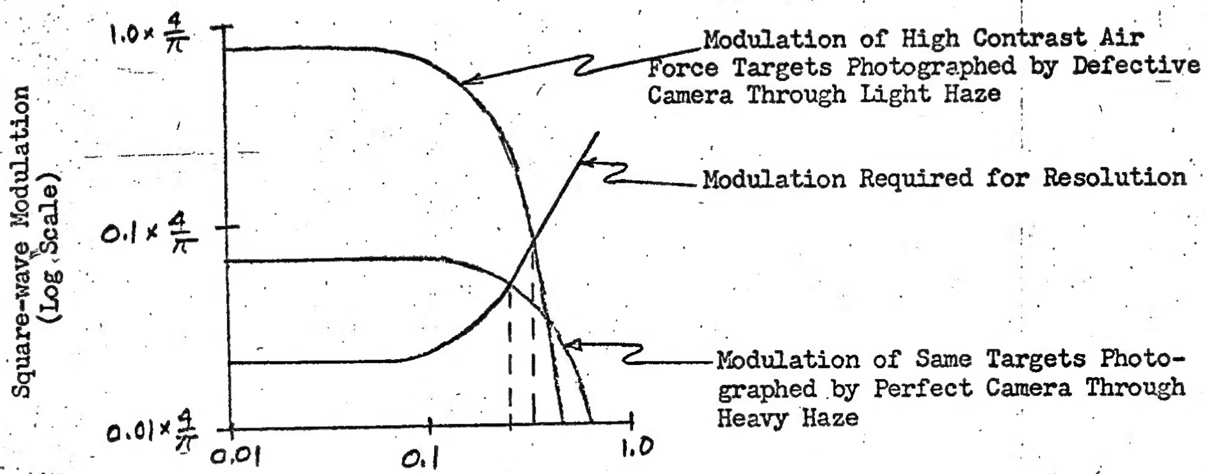


B - Resolution Change Due to Transfer Function Change

Figure __(3)__



A - Transfer Functions of Aerial Camera



B - Illustration of Higher Resolution Result Obtained by Poorer Camera Because of the Modulation Reduction Due to Atmospheric Scattering

would not permit anyone to state how much D. C. was originally accompanying the A. C. voltage nor how much of the D. C. was added at each of several different points. Thus, a target form immune to the effect of atmospheric scattering will not, by itself, help reveal the magnitude of veiling glare in the camera. However, this determination can be accomplished by comparative photography of ground targets.

Because atmospheric scattering reduces the target modulation and thus requires consideration in data reduction of target photography, thought has been given to installing targets above the atmosphere (or, at least, most of the atmosphere) where the target modulation would not be influenced by atmospheric effects. Assuming that the targets can somehow be made as motionless as ground based targets, they may well necessitate refocusing the camera. If these practical problems are solved, this is still a very expensive alternative to proper data reduction of the images of ground based targets and leads to torturous logistic complexities that are unwarranted.

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TYPES OF TARGETS AND THEIR ASSOCIATED REQUIREMENTS

The most satisfactory basis for predicting and explaining the behavior of an aerial camera is by the use of optical transfer functions to characterize the imaging system. An optimum target would thus be one which permits the transfer function to be determined. Three targets which do this are edge gradient, sine wave, and long line. Resolution targets give one point on the transfer function. Each of these forms is discussed below.

EDGE GRADIENT

Edge gradient targets are composed of two adjacent (relatively large) areas of differing brightness, where the brightness discontinuity occurs sharply at a (relatively long) straight line. Thus, edge gradient targets occur naturally in many cases (e.g., the edge of a runway, the shadow of a building, etc.) and they are a most valuable artificial target form because of this similarity. The use of natural edge gradients in denied areas for which ground truth can only be assumed, as an approximate camera performance monitor, assures that both good techniques and convenient instrumentation will be available to reduce data from targets of this form. Furthermore, the camera performance as determined from edge gradient targets provides the only direct verification of the validity of using naturally occurring edge gradients as a further performance measure.

Since the brightness discontinuity rather than relative or absolute brightness level of the target is the critical property, this target form is immune to the effect of atmospheric scattering. The contrast reduction caused by haze lowers the relative size of the brightness step presented to the camera, but the sharpness is maintained. In fact, it is this very immunity to haze

variation which makes the use of natural edge gradients valuable. If the absolute brightnesses of the edge gradient target are known, then a direct measure of modulation reduction due to atmospheric scattering is available.

The required dimension of a single direction edge gradient is 240 feet by 200 feet, as shown in Figure __(4)__. Two directions are required and could be fabricated compactly as illustrated in Figure __(5)__. Two edges can be provided in each direction by a sixty per cent enlargement, as shown in Figure __(6)__, and, as illustrated, this can also be used as a grayscale step-tablet. (Appendix A provides a detailed analysis of the required size of edge gradient targets.) These targets are adequate for all known and reasonable future systems.

The transfer function is obtained from a Fourier Transform of the exposure gradient on the film. Thus, sensitometric data and a microdensitometer trace of the edge are required, and it is convenient (but not necessary) to obtain the Fourier Transform with a digital computer.

LINE

In principle, line targets are comparable to edge gradient targets. They must be of the same size but they lack two virtues of the edge gradient form: (1) No gray scale is available "free"; and (2) A very high resolution camera might not be able to use the same line target as the C/M cameras. These targets thus have no advantage over edge gradient targets and are not recommended.

SINE-WAVE

These targets consist of paint patterns arranged so that the integrated brightness along a line element varies sinusoidally as the line is displaced perpendicular to its length. Each target provides one spatial frequency in one direction, and it is thus necessary to have several (e.g., four to six) targets

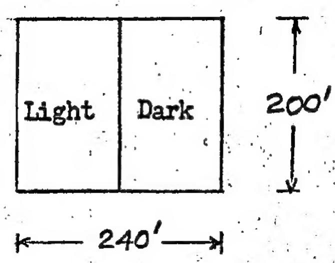

Fig. 4 - Single direction edge gradient target

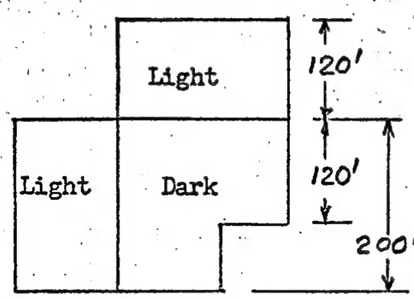

Fig. 5 - Two direction edge gradient target

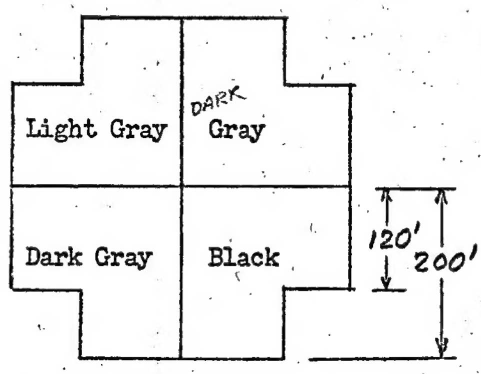

Fig. 6 - Double Two direction edge gradient and gray scale

aligned in each of two perpendicular directions. The transfer function is thus approximated by a curve drawn through the several determined points. The conceptual and arithmetic simplicity of this approach is attractive, but the target area is very large (approximately as shown in Figure (4) for the lowest spatial frequency, and then proportionately smaller for the several higher frequencies) and the targets must be accompanied by a gray scale on the ground. Since this gray scale could take the form of an edge gradient target, the sine-wave target form can be viewed as a trade in which greater ground target area is substituted for the computation of the Fourier Transform of the edge gradient. The sine-wave target requires the same kind of sensitometric data and microdensitometer trace as the edge gradient.

Sine-wave targets must be made for each spatial frequency of interest, and, thus, other cameras of higher resolution require further targets (which would be smaller). The size of the targets can reveal resolution dimensions of the using cameras, and this should be considered.

1c RESOLUTION TYPES

Over the years, many resolution test patterns have been proposed for cameras (e.g., National Bureau of Standards, [redacted] STAT others), but recently it has been conventional to employ Air Force three-bar patterns. The "resolution limit" on any of these patterns is the spatial frequency at which the modulation transfer function (i.e., the modulus of the optical transfer function) multiplied by the target modulation intersects the modulation detectability function for the target. Modulation detectability curves currently exist only for the Air Force three-bar pattern. The use of such targets can give only one point on the optical transfer function, but

these Air Force targets are still worthy of consideration because of their tie to recent practice in the Reconnaissance Community.

Figure __(7)__ illustrates a single frequency pattern, useful in two directions. Figure __(8)__ shows a normal array of six frequency steps. Figure __(9)__ is a possible layout of four groups which would decrease from [redacted] thus covering the range of C/M, and, with the smaller groups, also covering the range of realistic higher resolution systems. The overall size of the array is controlled almost entirely by coarsest spatial frequency of interest; as shown in Figure __(10)__, [redacted] STAT __(9)__ [redacted]. To this area, it is necessary to add a gray scale, which could take the form of an edge gradient target. As with the sine-wave target form, this extra ground area is a trade to reduce data reduction. Unfortunately, only one point on the transfer function is obtained, so these targets are not very useful in this regard unless the shape of the transfer function is invariant.

In common with sine-wave targets, the size of these targets reveals the resolution dimensions of interest.

FIG. ... NGLE FREQUENCY (K) TARGET

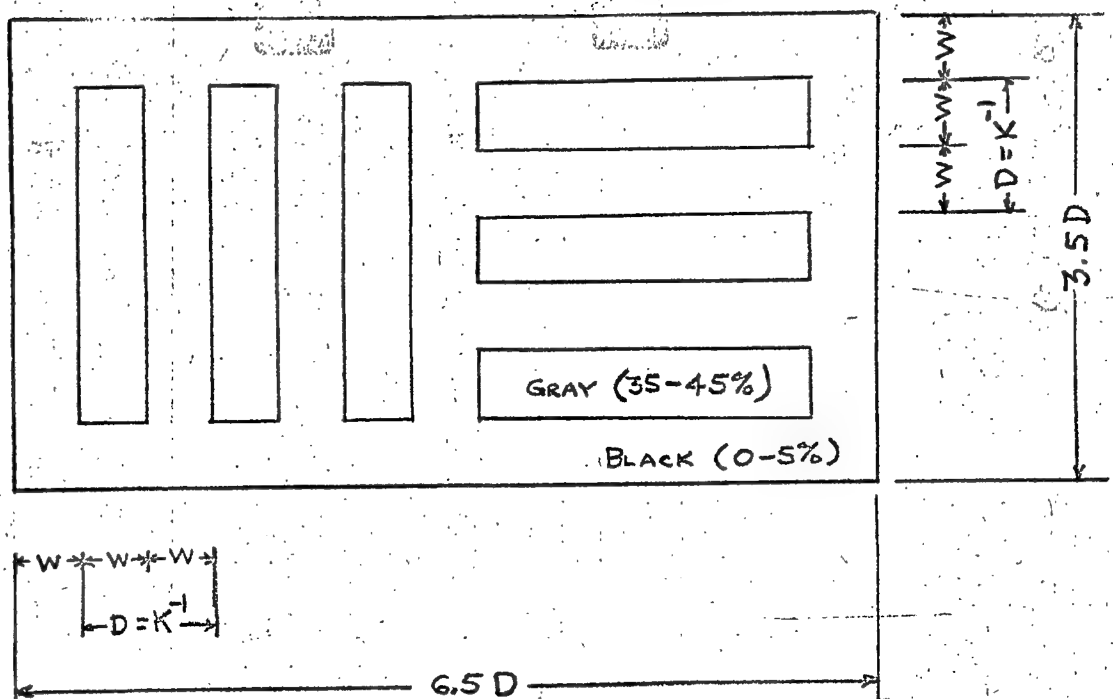

FIG. 8 - GROUP OF SIX TARGETS, VARYING BY $2^{-1/6}$

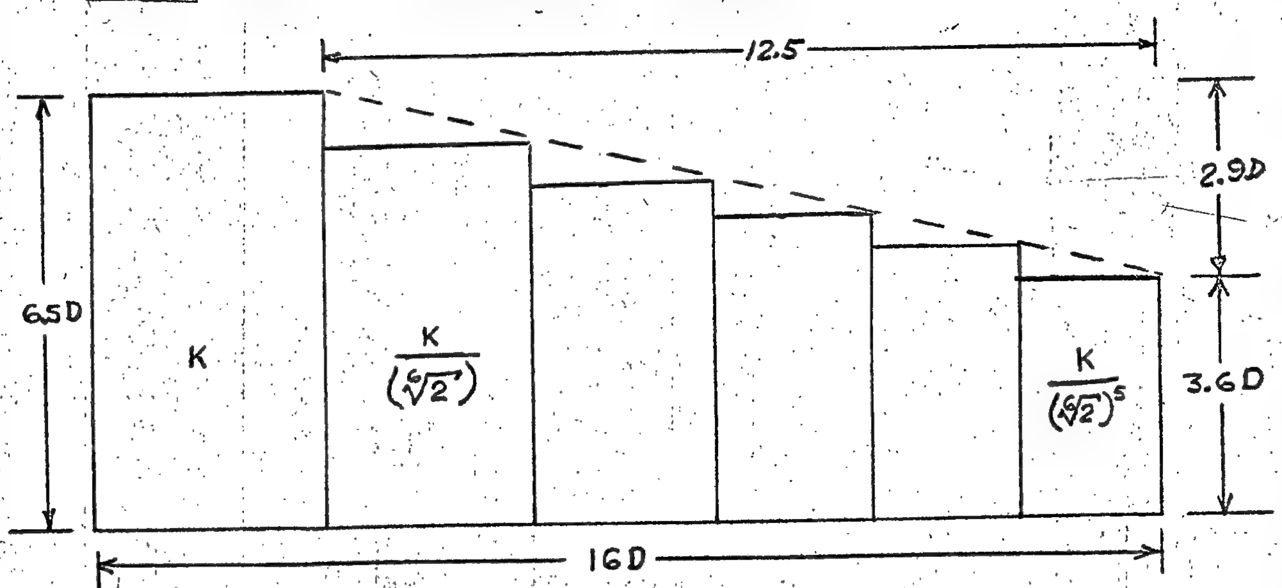

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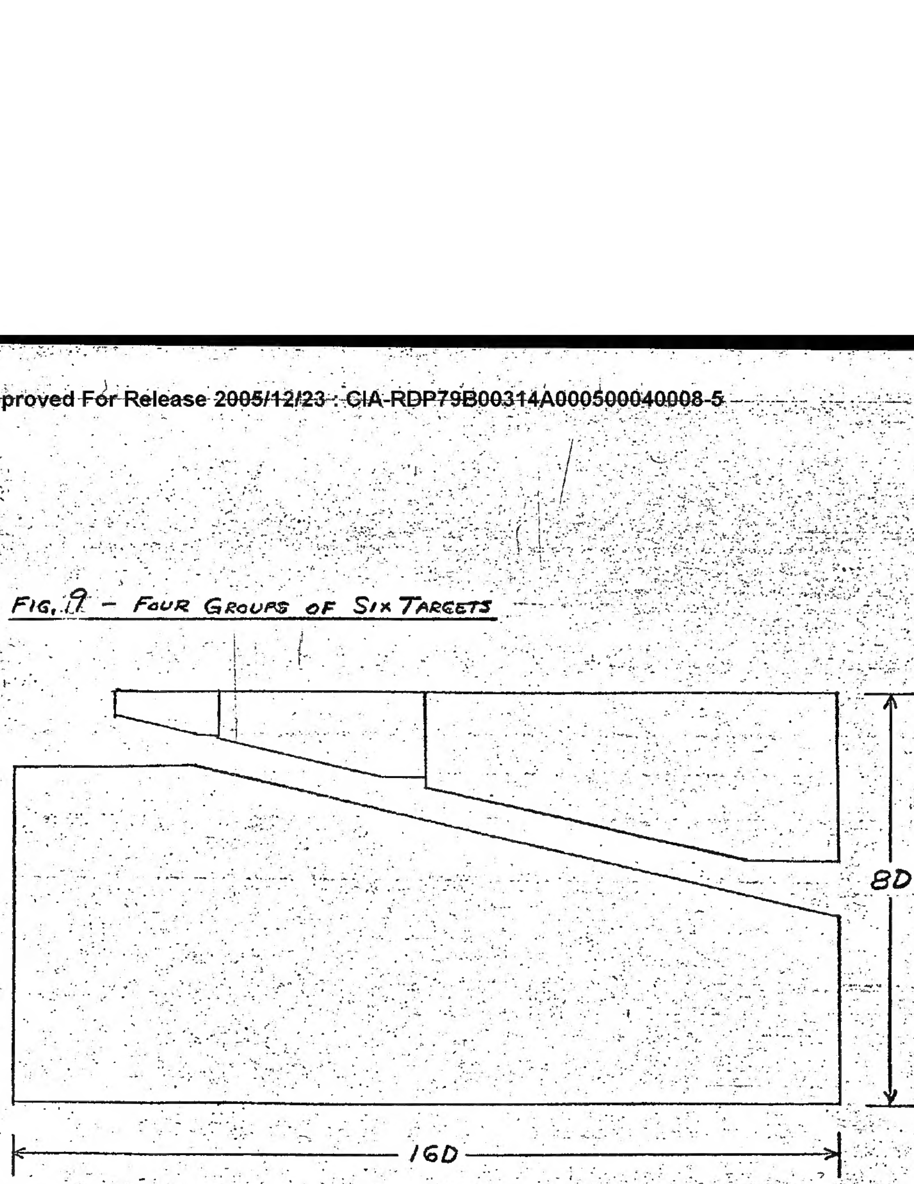
FIG. 9 - FOUR GROUPS OF SIX TARGETS



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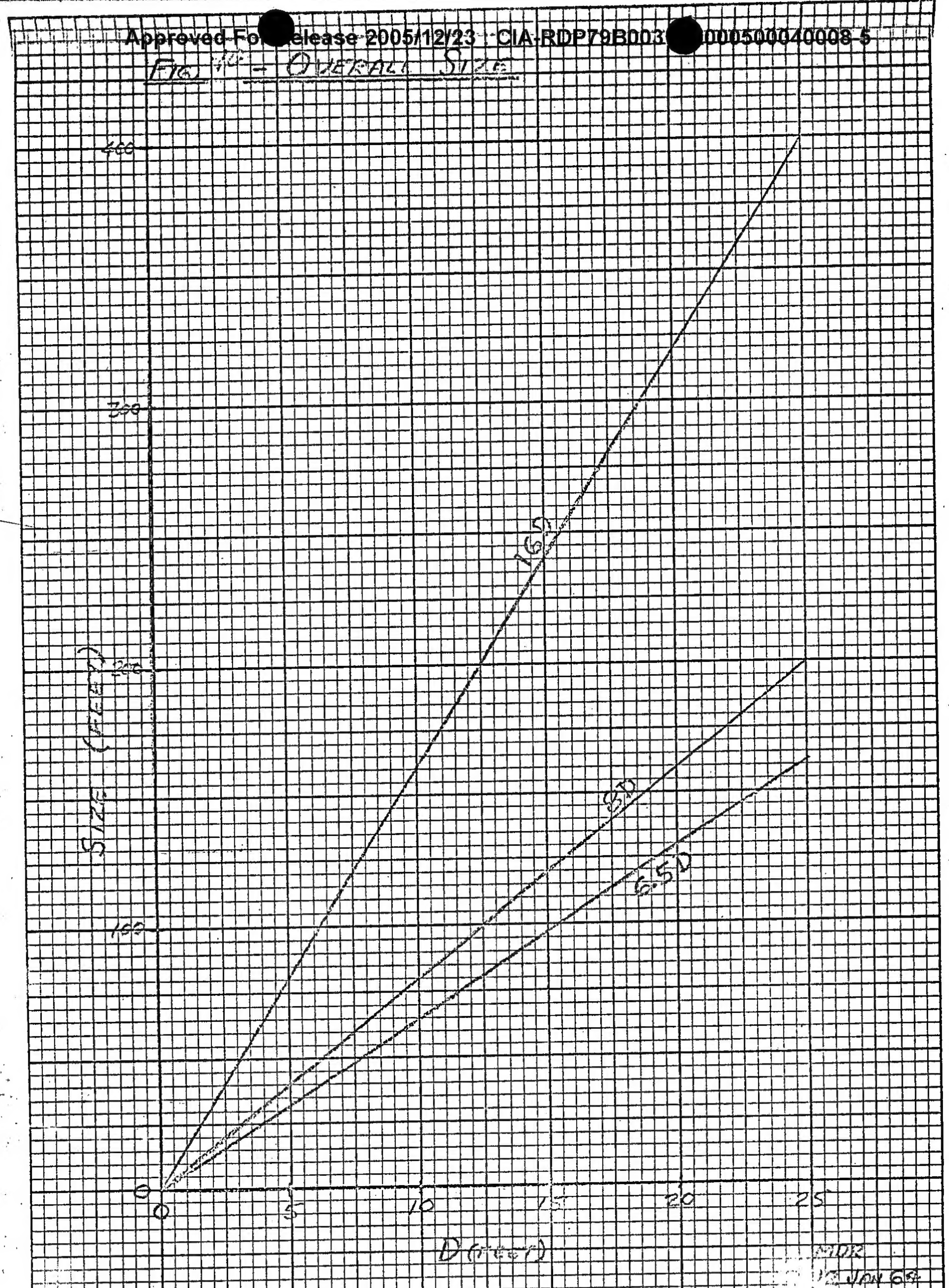
FIG 10 - OVERALL SIZE
400
300
200
100
0
SIZE (FEET)
16D
8D
6.5D
0
5
10
15
20
25
D (FEET)
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TARGET FABRICATION AND LOCATION

Conventionally, aerial targets are made with very black and very white paints and thus have an average reflectance close to fifty per cent. However, the average albedo (reflectance) of the earth is about twenty per cent. As the camera is normally programmed for exposure based on this earth value, the average reflectance of aerial targets should also be close to twenty per cent, thus assuring near optimum exposure.

Geographically, the targets should be located south of the normal snow limit to simplify maintenance. To further increase the optical accessibility, daytime cloud and fog cover should be minimized by proper site selection.

Finally, if ground brightness readings can be made of the targets and meteorological data obtained, both nearly simultaneous with the photography then it is possible to experimentally confirm postulated relations of modulation reduction and meteorological conditions. A time leeway of from five to fifteen minutes would seem reasonable, depending on how rapidly conditions changed, but the target site must be quite accessible if this measurement program is to be attempted.

RECOMMENDATIONS

As an absolute minimum, three edge gradient targets of the form shown in Figure __(4)_ should be constructed and maintained. C/M photography of these targets should be obtained at every possible opportunity until that time at which no further improvements of the C/M system is contemplated. Diagnostic airborne instrumentation should be operated simultaneously with the target photography whenever it is available. The reduction of operational coverage resulting from these engineering passes is an investment to improve future operational coverage and is probably so insignificant that it will never be missed.

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More extensive targets are very desirable. Money and space permitting, about six edge gradient targets of the form shown in Figure _(9)__ should be constructed and maintained. Of lower priority, Air Force targets of the form shown in Figures _(17)_, _(18)_, and _(19)_ could be added if still further money and space were available.

Because non-image forming exposure (corona, radiation, light leak, and veiling glare) is a very serious problem with C/M photography, it is valuable to capitalize upon these targets and CORN overflights of these targets <u>until the extraneous light problem is under control</u>. Specifically, nearly simultaneous overflights (say within fifteen minutes either way) of the targets should be made at a high enough altitude so that a camera with negligible light leaks can obtain photographs of the same targets as seen with all of the significant atmospheric modulation reduction. When this camera has the same film-filter combination as C/M and views the targets from the same angle and with the same illumination as C/M, then the difference in modulation reduction perceived by the two cameras is a measure of the unwanted exposure in C/M.